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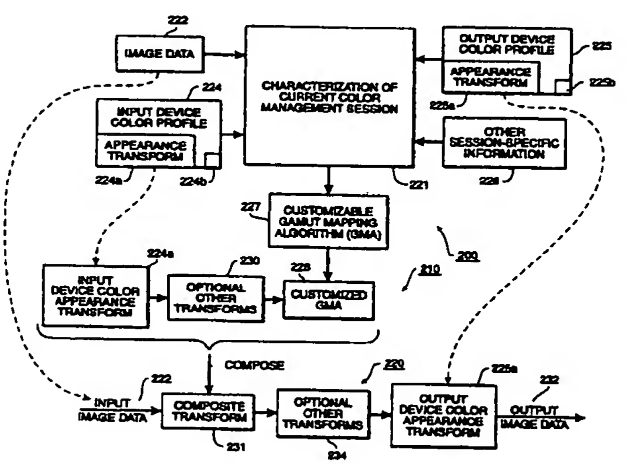
(54) Title: COMPOSITE COLOR TRANSFORMATION USING CUSTOMIZED GAMUT MAPPINGS



(57) Abstract: A color management system that transforms input image data (224) from an input colorant space to an output colorant space (225) using input and output device appearance transforms and a customizable gamut mapping algorithm (227). The gamut mapping algorithm is customizable based on the color management session in question, and in particular may be customizable based on the content of the image data, based on a comparison between input device appearance transforms and output device appearance transforms, or based on viewing conditions, output conditions or print media involved. According to the invention, the customizable gamut mapping algorithm is customized based on the current color management session, and the customized gamut mapping algorithm is composited with the input device appearance transform and/or the output device appearance transform thereby yielding one or more transformations that can be applied to the input image data more efficiently than if the transformations (including the gamut mapping algorithm) were applied individually.

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COMPOSITE COLOR TRANSFORMATION USING CUSTOMIZED GAMUT MAPPINGS

BACKGROUND OF THE INVENTION

Field Of The Invention

The present invention concerns a color management system in which color transformations including a gamut mapping are composited together into a single color transformation, with the gamut mapping being customized (or tailored) in dependence on characteristics of the current color management session, such as being customized based on the image data being managed, or based on a relationship between input device gamut and output device gamut.

Description Of The Related Art

Known color management systems transform images from an input colorant space corresponding to an input device into an output colorant space corresponding an output device. First, input image data is transformed into an intermediate color space

from the input device colorant space using an input device color appearance transform. The intermediate color space is often referred to as a profile connection space, or PCS, and may be a device independent color space or a perceptual color space. The intermediate representation of the image data is subjected to gamut mapping so as to ensure that all colors in the transformed image data are representable in the output device. Then, the gamut mapped image data is transformed into the output colorant space using an output device color appearance transform. U.S. Patent 5,463,480 to MacDonald describes one such color management system.

The input and output device color appearance transforms are transformations that are often embodied in mathematical expressions or in look-up tables (LUTs) that may be either one-dimensional or multi-dimensional. In the case of a LUT for an input device appearance transform, the LUT stores values in the PCS corresponding to spaced samples in the input device color space. A typical input device appearance transform, corresponding for example to a scanner, stores values in Jch or Jab coordinates (i.e., the CIECAM97s perceptual color space) corresponding to a three-dimensional grid of 9x9x9 samples in each of the red and green and blue components for the scanner. Output device appearance transforms, for example that of a printer, contain corresponding values of the output device colorants (such as cyan, yellow and magenta) based on spaced samples in Jch or Jab coordinates.

One of the more difficult challenges for color management systems is determining how to reproduce colors from the original image that cannot be produced within the gamut of colors on the destination device. "Gamut mapping" is the attempt

to map colors in a pleasing way. There are many gamut mapping algorithms in use today, and although they are ordinarily given in the form of mathematical expressions or look-up tables, they also are transformations of colors.

Use of these transformations (i.e., the input and output device appearance transforms and gamut mappings), whether they be LUTs or mathematical expressions or any other form of transformation, requires significant processing power. For example, because LUTs contain only spaced samples, interpolation is necessary to use these LUTs for any one set of image data, since it is unlikely that the image data will contain only values falling exactly at the LUT samples. Interpolation techniques are well known and include, for example, trilinear and tetrahedral interpolation. However, since interpolation must be applied to each and every piece of image data, both forward through the input device appearance transform and out through the output device appearance transform, processing is extensive and time consuming. This is compounded by gamut mapping, which also must be applied against each piece of transformed image data.

U.S. Patent 5,432,906 to Newman proposes one solution to the amount of processing power needed, by creating a composite transform which is equivalent to a sequential application of multiple color transforms from an input color space to an output color space. Since the transforms themselves are composited into a single transform, Newman's proposal lowers data processing overhead because image data need only be transformed through a single composite transform, rather than through multiple transforms.

The Newman proposal is disadvantageous, however, since once the composite transformation has been obtained, it is immutable and cannot be changed based on circumstances of each different color management session. For example, there are many situations in which it is preferable to customize or to tailor the gamut mapping algorithm based on the color management session. As one example, it is often preferable to tailor the gamut mapping algorithm based on the precise nature of the image data. For image data that falls entirely within the output device gamut, the gamut mapping algorithm need not be applied at all; whereas for increasingly out-of-gamut image data, increasingly compressive gamut mappings are applied. However, because the Newman system pre-computes a composite transform, such flexibility is not achievable.

SUMMARY OF THE INVENTION

It is an object of the invention to address the foregoing difficulty by forming a composite transform that incorporates gamut mapping, with the gamut mapping being customized or otherwise tailored for the current color management session. Because the gamut mapping is customized for the current color management session, color effects that would not even have been recognized until after the overall color management session was in place can easily be compensated through customization.

Thus, in one aspect, the invention is a color management system that operates with an input device appearance transform and an output device appearance transform together with a customizable gamut mapping algorithm so as to transform an image from an input colorant space to an output colorant space during a color management session. According to the invention, the gamut mapping algorithm is

customized to the color management session in question, and then the gamut mapping algorithm is applied to either the input device appearance transform or the output device appearance transform, or both, so as to result in a composited transform that incorporates a customized gamut mapping.

Examples of suitable gamut mapping algorithms, that are customizable based on a color management session, are gamut mapping algorithms that depend on image data, gamut mapping algorithms that depend on a comparison between input and output device gamuts (such as the GCUSP, CLLIN and CARISMA algorithms), and gamut mapping algorithms that depend on current printing or viewing conditions. Other customizable gamut mapping algorithms may also be used, with customization being dependent upon the current color management session, such as parameterized gamut mapping algorithms whose parameters depend on information from the current color management session, such as information pertaining to the input image, the input device gamut, the output device gamut, or the output conditions such as viewing conditions or recording medium.

For example, the input device appearance transform and/or the output device appearance transform may include gamut boundary descriptors, and the gamut boundary descriptors might be utilized by a parameterized gamut mapping algorithm so as to generate a customized gamut mapping algorithm specific for a transformation from the input device to the output device.

Compositing of the gamut mapping algorithm with other transforms may be a full compositing, so as to yield a single transform from the input colorant space to the output colorant space, or may be a partial compositing, such as a composite

transform from the input device space through to gamut-mapped device independent or perceptual color space. In addition, other transformations might also be applied, such as transformations tailored to achieve particular color effects, or to model color appearance.

In one particularly preferred arrangement, direct or indirect results of the input device appearance transform are gamut-mapped with the customized gamut mapping algorithm so as to yield a gamut-mapped composite transformation from input colorant space to a gamut-mapped device independent or perceptual color space. This arrangement is preferred since the input device appearance transform represents all possible input image colors in a compact way. Accordingly, since the input device appearance transform represents all possible image colors in a compact way, customized gamut mapping can be applied more efficiently than if the gamut mapping were applied to input image data transformed through the input device appearance transform. Thus, since the image can be expected to contain multiple occurrences of a large number of colorant values, particularly in the case of computer-generated images, processing according to the invention largely reduces redundant processing.

As an additional preferred embodiment, output device appearance transform can be applied to the foregoing partial composite transform, so as to yield a single composite transform from the input colorant space to the output colorant space in which a gamut mapping algorithm is customized to the particular color management session in question.

This brief summary has been provided so that the nature of the invention may be understood quickly. A more complete understanding of the invention can be obtained by reference to the

following detailed description of the preferred embodiment thereof in connection with the attached drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a view showing the outward appearance of a representative computing system.

Figure 2 is a detailed block diagram showing the internal architecture of a host processor of the computing equipment.

Figure 3 is a functional block diagram illustrating functionality of a color management system according to the invention.

Figure 4 is a detailed flow diagram illustrating the sequence of steps performed by the color management module of Figure 3.

Figure 5 shows a functional block diagram illustrating functionality of a further embodiment of the invention.

Figure 6 is a flow diagram illustrating the sequence of step performed by the color management module of Figure 5.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present invention is generally directed to a color management system that customizes a customizable gamut mapping algorithm (GMA) based on session-specific information of a color management session, prior to compositing the customized gamut mapping algorithm with other color transformations. The present invention can be implemented in color management systems which are used to map color image data from the color space of one device, such as a monitor or a scanner, to the color space of another device, such as a printer. A color management system according to the present invention may be incorporated in an output device driver in a

computing device such as a printer driver, it may be embedded in the firmware of an output device such as a printer, or it may be provided in a stand-alone color management application for use on a general purpose computer. It should be understood that the present invention is not limited to these embodiments and that the present invention may be used in other environments in which color management is used.

Figure 1 is a view showing the outward appearance of a representative computing system including computing equipment, peripherals and digital devices which may be used in connection with the practice of the present invention, which in this case is implemented as a stand-alone color management module in the computing system. Computing equipment 40 includes host processor 41 which comprises a personal computer (hereinafter "PC"), preferably an IBM PC-compatible computer having a windowing environment such as Microsoft Windows 95, Windows 98 or Windows NT, although it may be a Macintosh or a non-windows based computer. Provided with computing equipment 40 are color monitor 43 including display screen 42, keyboard 46 for entering text data and user commands, and pointing device 47. Pointing device 47 preferably comprises a mouse for pointing and for manipulating objects displayed on display screen 42.

Computing equipment 40 includes a computer-readable memory medium for storing computer-executable process steps, here computer fixed disk 45 and/or floppy disk drive 44. Floppy disk drive 44 provides a means whereby computing equipment 40 can access information, such as image data, computer-executable process steps, application programs, etc. stored on removable memory media. A similar CD-ROM interface (not shown) may be

provided for computing equipment 40 through which computing equipment 40 can access information stored on removable CD-ROM media.

Printer 50 is a printer, preferably a color bubble jet printer, which forms color images on a recording medium such as coated or uncoated paper or transparencies or the like. In addition, image input equipment is provided, such as digital color scanner 70 for scanning documents and images into computing equipment 40 and digital color camera 60 for sending digital images to computing equipment 40. Of course, computing equipment 40 may acquire digital image data from other sources such as a digital video camera or from a local area network or the Internet via network interface bus 80.

Figure 2 is a detailed block diagram showing the internal architecture of host processor 41 of computing equipment 40. As shown in Figure 2, host processor 41 includes central processing unit (CPU) 113 which interfaces with computer bus 114. Also interfacing with computer bus 114 are fixed disk 45, network interface 109, random access memory (RAM) 116 for use as main memory, read only memory (ROM) 117, floppy disk interface 119, display interface 120 to monitor 43, keyboard interface 122 to keyboard 46, mouse interface 123 to pointing device 47, scanner interface 124 to scanner 70, printer interface 125 to printer 50, and digital camera interface 126 to digital camera 60.

Main memory 116 interfaces with computer bus 114 so as to provide RAM storage to CPU 113 during execution of software programs such as an operating system, application programs and device drivers. More specifically, CPU 113 loads computer-executable process steps from fixed disk 45, another storage device, or some other source such as a network, into a region of main memory 116. CPU 113

then executes the stored process steps from main memory 116 in order to execute software programs such as an operating system, application programs and device drivers. Data such as color images can be stored in main memory 116, where the data can be accessed by CPU 113 during the execution of computer-executable process steps which use or alter the data.

As also shown in Figure 2, fixed disk 45 contains operating system 130, which is preferably a windowing operating system although other operating systems may be used, application programs 131, such as image processing applications that may include an embedded color management module, and plural device drivers that may also include embedded color management modules, including a digital camera driver 132, monitor driver 133, printer driver 134, scanner driver 135, and other device drivers 136. Fixed disk 45 also includes image files 137, other files 138, digital camera color appearance transform 139 for digital camera 60, monitor color appearance transform 140 for monitor 43, printer color appearance transform 141 for printer 50, scanner color appearance transform 142 for scanner 70, and other color appearance transforms 143 for other devices and peripherals (not shown). Each of these device appearance transforms includes a color transformation that characterizes the color attributes of the device in question. Usually, the device appearance transform includes a transformation from a device dependent color space to a device independent color space (for an input device), from a device independent color space to a device dependent color space (for an output device), or both. Suitable device appearance transforms are described in "Color Management In The Graphics Arts

And Publishing", by Tony Johnson (Pira International, 1996).

The present invention is preferably performed by computer-executable process steps which are stored on fixed disk 45 for execution by CPU 113, either as an integrated part of a device driver, such as printer driver 134, or as one of application programs 131 for performing image processing. In the present embodiment, the invention is performed by stand-alone color management module (CMM) 144.

Figure 3 is a functional block diagram illustrating functionality of a color management system according to the invention, such as color management module 144. As shown in Figure 3, color management module 144 operates in three phases of functionality: a customization processing phase 200 during which a customizable gamut mapping algorithm is customized for the current color management session, a pre-processing phase 210 during which the customized gamut mapping algorithm is applied to one or more transforms so as to result in a composite transform that incorporates the customized gamut mapping algorithm, and a data processing phase 220 during which input image data is transformed from its input colorant space through the composite transform together with any other transforms needed to produce output color data in an output colorant space.

In more detail, block 221 characterizes the current color management session based on components that make up the session in question. Those components include one or more of the input image data 222, the input device color profile 224 which includes appearance transform 224a, the output device color profile 225 which includes appearance transform 225a, and other session-specific

information 226. The input and output device profiles 224 and 225 are typically arranged as computer files stored on a memory medium such as disk 45 and include information about the input and output devices such as the appearance transform, gamut boundary descriptors and other information usable in a color management process. Based on one or more of these inputs, the current color management session is characterized by block 221. For example, the input device profile and/or the output device profile may include gamut boundary descriptors as signified respectively at 224b and 225b. Based on the gamut boundary descriptors, block 221 may characterize the current color management session based on differences between the input color gamut as defined by boundary descriptor 224b and the output color gamut as defined by boundary descriptor 225b. The difference between these gamuts signifies the extent to which gamut mapping is needed, and may result in situations where no gamut mapping is necessary, moderate gamut mapping is necessary, or significant gamut mapping is necessary. Such information is provided to block 227 which customizes a customizable gamut mapping algorithm (GMA) so as to yield customized GMA 228.

As another example, block 221 may extract the color content of image data 222 so as to determine the extent to which gamut mapping is needed so as to fit the color image data 222 into the output device gamut, which may be defined by gamut boundary descriptor 225b. Again, such information is provided to block 227, which customizes a customizable GMA so as to produce customized GMA 228.

As yet a further example, other session-specific information from input 226 may be provided to block 221, with such examples of session-specific

information including output conditions such as viewing conditions (color temperature, target audience, and the like), recording medium type (in the case of a printed output), and current environmental conditions (such as temperature) to the extent that such environmental conditions might affect resulting color output. Based on such session-specific information, block 221 characterizes the color management session and passes the characterization thereof on to block 227 which customizes the customizable GMA so as to result in customized GMA 228.

The foregoing examples are not to be construed as limiting; rather, it is to be understood that any suitable characterizations of the current color management session may be provided by block 221 so as to customize a customizable GMA. In particular, it is to be understood that one or a combination of more than one of the foregoing examples may be utilized in the characterization of the current color management session.

Examples of customizable GMAs to which the characterization is applied in block 227 are gamut mapping algorithms that depend on characteristics of the current color management session, such as GMAs that depend on a comparison between input and output device gamuts (such as the known GCUSP, CLLIN, and CARISMA algorithms), gamut mapping algorithms that depend on input image data, and gamut mapping algorithms that depend on current printing or viewing conditions or other session-specific conditions. In particular, the invention contemplates use of parameterized GMAs, where parameters for the GMA depend on information from the current color management session, as provided from block 221. Suitable GMAs for use in block 227 include GMAs that are mathematical expressions or a

sequence of computer instructions, or GMAs that are embodied as one- or multi-dimensional look-up tables, or combinations of the foregoing, or any suitable transformation from one device gamut to anther device gamut.

Pre-processing phase 210 involves application of customized GMA 228 to one or more color transforms so as to result in a composited color transform that incorporates the customized GMA. In the example of Figure 3, customized GMA 228 is post-applied to a direct or indirect result of transformation processing according to the input device appearance transform 224a. Figure 3 illustrates optional other transforms 230 that are applied sequentially after transforms according to the input device appearance transform 224a. Such other transforms 230 might include, for example, transforms according to a color appearance model into a color appearance space, or transforms for aesthetic purposes such as a change in hue. The effect of transform processing according to input device appearance transform 224a and/or optional other transforms 230 is to obtain a transformation from an input device colorant space to a device independent color space or a perceptual color space. As shown at 210, customized GMA 228 is post-applied to such a transformation so as to result in composite transform 231.

The precise technique of how to post-apply customized GMA 228 to the direct or indirect result of transformation processing according to input device appearance transform 224a depends on the nature of the respective transforms involved. For example, in a situation wherein input device appearance transform 224a and customized GMA 228 are both stored as mathematical expressions, composite transform 231 is most conveniently formed as a

multi-dimensional look-up table formed of an NxNxN grid of equally spaced values in the input colorant space. Entries in each grid correspond to the result of mathematical and sequential processing of each equally spaced point in the input colorant space, first by the input device color appearance transform and then by the customized GMA. The result will ordinarily be in a device independent or perceptual color space, such as a profile connection space (PCS) or the CIECAM97s color space (whose coordinates are Jch or Jab).

In an alternative example, where input device appearance transform 224a is stored as a one- or multi-dimensional look-up table, and customized GMA 228 is stored as a mathematical expression, composite transform 231 is most conveniently formed as a multi-dimensional look-up table in which each entry in the input device appearance transform 224a is replaced by a transformation of the entry through application of the customized GMA.

Reverting to Figure 3, data processing phase 220 involves transformation of input image data 222 first through composite transform 231 and thence through output device appearance transform 225a so as to result in output data 232 in the output colorant space. As shown in Figure 3, it is also possible to provide optional other transforms 234, such as transforms complementary to transforms 230. For example, in a situation where transform 230 is a color appearance model and yields results in a perceptual color space, transform 234 might pre-apply an inverse color appearance model so as to transform to a color space suitable for input to the output device appearance transform 225a.

Figure 4 is a detailed flow diagram illustrating the sequence of steps performed by color management module 144 according to the

functional block diagram shown in Figure 3. The process steps illustrated in Figure 4 are stored as computer executable process steps executable by CPU 113 and stored on a computer readable medium such as disk 45. Briefly, according to the process steps shown in Figure 4, color management uses input and output device appearance transforms together with a customizable gamut mapping algorithm so as to transform input color data from an input colorant space to output color data in an output colorant space, and includes customization of the gamut mapping algorithm based at least in part on the current color management session, and application of the customized gamut mapping algorithm with other transforms such as the input or output device appearance transform, or both, so as to result in a composited transform that incorporates the customized gamut mapping algorithm. Thereafter, the input image data is transformed from the input colorant space to the output colorant space using the composited transform together with any additional transforms needed to complete the transformation.

In more detail, in steps S401 through S403, the input image data, the input and output device appearance transforms, and any other session-specific information, are accessed so as to characterize the current color management session (step S405). As mentioned previously with respect to characterization processing by block 221, not necessarily all of the above are needed to characterize a current color management session. Thus, it is possible for characterization processing in step S405 to characterize the current color management session based on less than all of the input image data, the input and output device appearance transforms, and other session-specific

information. In addition, it is possible for characterization processing in step S405 to characterize the current color management session based on information contained or inferable from the above; for example, it is possible for characterization processing in step S405 to characterize the color management session based on gamut boundary descriptors stored together with the input and output device appearance transforms.

Flow proceeds then to step S406 in which a customizable GMA is customized with the characterization of the current session. Customizing step S406 proceeds, for example, by a supply of parameters from characterization processing step S405 to a parameterized GMA, so as to result in a customized GMA.

Flow then proceeds to step S407 in which the customized GMA is applied to the input device appearance transform, or to a transformed result of the input device appearance transform, so as to obtain a composite transform that incorporates the customized GMA. As mentioned previously, the composite transform may be obtained in the form of a look-up table such as a look-up table in which values from the input device appearance transform have been replaced by gamut-mapped values from the customized GMA. Alternatively, it is possible to obtain a composited transformation in equation form, or in any other format by which a composite transform that incorporates the customized GMA is obtained. It is further to be understood that the customized GMA might not be applied to a direct result of the input device appearance transform transformation, but rather applied to an indirect result thereof, such as a result that has been further processed by optional other transforms 230 (see Figure 3).

Flow then advances to step S409 in which the input color image data is transformed through the composite transform, so as to obtain gamut-mapped and transformed input image data in an intermediate color space such as a perceptual color space or a device independent color space. The transformed image data in the intermediate color space is thereafter transformed (step S410) through the output device appearance transform, together with any other optional transforms 234 (see Figure 3) that might be desired or needed to complete the transformation of the input image data in the input colorant space to output image data in an output colorant space.

Figure 5 shows a functional block diagram of a further embodiment of the invention. One way that the functional block diagram of Figure 5 differs from that of Figure 3 is in the nature of the composite transform that is obtained during the pre-processing phase: in the Figure 3 embodiment, the composite transform is a partial transform that transforms from an input colorant space to an intermediate colorant space, whereas in Figure 5 the composite transform is a complete transform that transforms, in a single transformation, from an input colorant space to an output colorant space.

In Figure 5, blocks having functions similar to those in Figure 3 have received similar reference numbers. Thus, three functional phases are shown: a customization processing phase 300 that customizes a customizable gamut mapping algorithm for the current color management session, a pre-processing phase 310 that composes a composite transformation so as to obtain, in a single transform, a transformation from input colorant space to output colorant space, and a data processing phase 320 in which image data is

transformed through the composite transform to yield output data in an output colorant space.

In pre-processing phase 310, the composite transform that is obtained is a composite transform from input colorant space all the way through to an output colorant space, utilizing at least the input device appearance transform 324a, the customized GMA 328, and the output device appearance transform 325a. As shown in Figure 5, optional other transforms may also be applied, such as transforms 330 and 334 that apply a color appearance model and complement thereof, respectively.

Figure 6 is a flow diagram corresponding to the functional block diagram of Figure 5. Steps S601 through S606 are similar to steps S401 through S406, respectively, of Figure 4. In step S607, all transforms are composited with the customized GMA so as to yield a single composite transform (such as composite transform 331 is Figure 5) that transforms from an input colorant space to an output colorant space. Thereafter, in step S608, the input color image data is transformed through the single composite transform so as to yield output data in the output colorant space.

The invention has been described with respect to particular illustrative embodiments. It is to be understood that the invention is not limited to the above-described embodiments and that various changes and modifications may be made by those of ordinary skill in the art without departing from the spirit and scope of the invention.

WHAT IS CLAIMED IS:

1. A color management method using an input device appearance transform and an output device appearance transform together with a customizable gamut mapping algorithm so as to transform image data from an input colorant space to an output colorant space during a color management session, said method comprising the steps of:

customizing the gamut mapping algorithm based at least in part on the color management session in question; and

applying the customized gamut mapping algorithm to either the input device appearance transform or the output device appearance transform, or both, so as to result in a composited transform that incorporates a customized gamut mapping.

2. A method according to Claim 1, wherein the customizable gamut mapping algorithm depends on the image data, and wherein said customizing step customizes based on the image data.

3. A method according to Claim 1, wherein the customizable gamut mapping algorithm depends on a comparison between input and output device gamuts, and wherein said customizing step customizes based on the comparison between input and output device gamuts.

4. A method according to Claim 1, wherein the customizable gamut mapping algorithm depends on the viewing conditions, and wherein said customizing step customizes based on the viewing conditions.

5. A method according to Claim 1, wherein the input device appearance transform and/or the

output device appearance transform are stored in respective input and output device profiles which further store gamut boundary descriptors, and wherein said customization step customizes based on the gamut boundary descriptors.

6. A method according to Claim 1, wherein said applying step yields a single transform from the input colorant space to the output colorant space.

7. A method according to Claim 1, wherein said applying step applies the gamut mapping algorithm to the input device color appearance transform, or a result thereof, so as to yield a composite transform from the input device space through to a gamut-mapped device independent or perceptual color space.

8. A color management method using an input device appearance transform and an output device appearance transform together with a customizable gamut mapping algorithm so as to transform image data from an input colorant space to an output colorant space during a color management session, said method comprising the steps of:

customizing the gamut mapping algorithm based at least in part on the color management session in question; and

applying the customized gamut mapping algorithm to a direct or indirect result of the input device appearance transform so as to result in a composite transform from an input colorant space to a customized gamut-mapped result in a device independent or perceptual color space.

9. A method according to Claim 8, further comprising the steps of:

transforming the image data in the input colorant space using the composite transform; and

transforming the transformed image data using the output device appearance transform, so as to yield an overall transformation of the image data from an input colorant space to an output colorant space.

10. A method according to Claim 8, wherein the customizable gamut mapping algorithm depends on the image data, and wherein said customizing step customizes based on the image data.

11. A method according to Claim 8, wherein the customizable gamut mapping algorithm depends on a comparison between input and output device gamuts, and wherein said customizing step customizes based on the comparison between input and output device gamuts.

12. A method according to Claim 8, wherein the customizable gamut mapping algorithm depends on the viewing conditions, and wherein said customizing step customizes based on the viewing conditions.

13. A method according to Claim 8, wherein the input device appearance transform and/or the output device appearance transform are stored in respective input and output device profiles which further store gamut boundary descriptors, and wherein said customization step customizes based on the gamut boundary descriptors.

14. A method according to Claim 8, wherein said applying step applies the gamut mapping

algorithm to the input device color appearance transform so as to yield a composite transform from the input device space through to a gamut-mapped device independent or perceptual color space.

15. A color management system which transforms input image data from an input colorant space to an output colorant space during a color management session, the transformation of the input image data being based at least in part on an input device appearance transform, an output device appearance transform, and a customizable gamut mapping algorithm, wherein the input device appearance transform acts to transform from an input colorant space to an intermediate color space comprised of a device independent or a perceptual color space, wherein the output device appearance transform acts to transform from the intermediate device independent or perceptual color space to an output colorant space, and wherein the input and the output device appearance transforms are represented by look-up tables, said color management system comprising:

a customization processor that customizes the customizable gamut mapping algorithm for the color management session in question;

a pre-processor that, for each entry in the input device look-up table, or a transformed result of such entry, applies the customized gamut mapping algorithm so as to obtain a gamut-mapped result in the intermediate device independent or perceptual color space, said pre-processor replacing the gamut-mapped result in place of an original entry in the input device look-up table, thereby yielding a gamut-mapped transform that transforms from the input colorant space to the intermediate device independent or perceptual color space; and

a data processor that transforms the image data using the gamut-mapped transform so as to obtain gamut-mapped image data transformed to the intermediate device independent or perceptual color space, said processor thereafter transforming the gamut-mapped image data from the intermediate device independent or perceptual color space to the output colorant space using the output device appearance transform.

16. A system according to Claim 15, wherein the customizable gamut mapping algorithm depends on the image data, and wherein said customizing step customizes based on the image data.

17. A system according to Claim 15, wherein the customizable gamut mapping algorithm depends on a comparison between input and output device gamuts, and wherein said customizing step customizes based on the comparison between input and output device gamuts.

18. A system according to Claim 15, wherein the customizable gamut mapping algorithm depends on the viewing conditions, and wherein said customizing step customizes based on the viewing conditions.

19. A system according to Claim 15, wherein the input device appearance transform and/or the output device appearance transform are stored in respective input and output device profiles which further store gamut boundary descriptors, and wherein said customization step customizes based on the gamut boundary descriptors.

20. A color management apparatus using an input device appearance transform and an output device appearance transform together with a customizable gamut mapping algorithm so as to transform image data from an input colorant space to an output colorant space during a color management session, comprising:

a program memory for storing process steps executable to perform a method according to any of Claims 1 to 14; and

a processor for executing the process steps stored in said program memory.

21. Computer-executable process steps stored on a computer readable medium, said computer-executable process steps for transforming image data from an input colorant space to an output colorant space during a color management session using an input device appearance transform and an output device appearance transform together with a customizable gamut mapping algorithm so as to transform, said computer-executable process steps comprising process steps executable to perform a method according to any of Claims 1 to 14.

22. A computer-readable medium which stores computer-executable process steps, the computer-executable process steps for transforming image data from an input colorant space to an output colorant space during a color management session using an input device appearance transform and an output device appearance transform together with a customizable gamut mapping algorithm so as to transform, said computer-executable process steps comprising process steps executable to perform a method according to any of Claims 1 to 14.

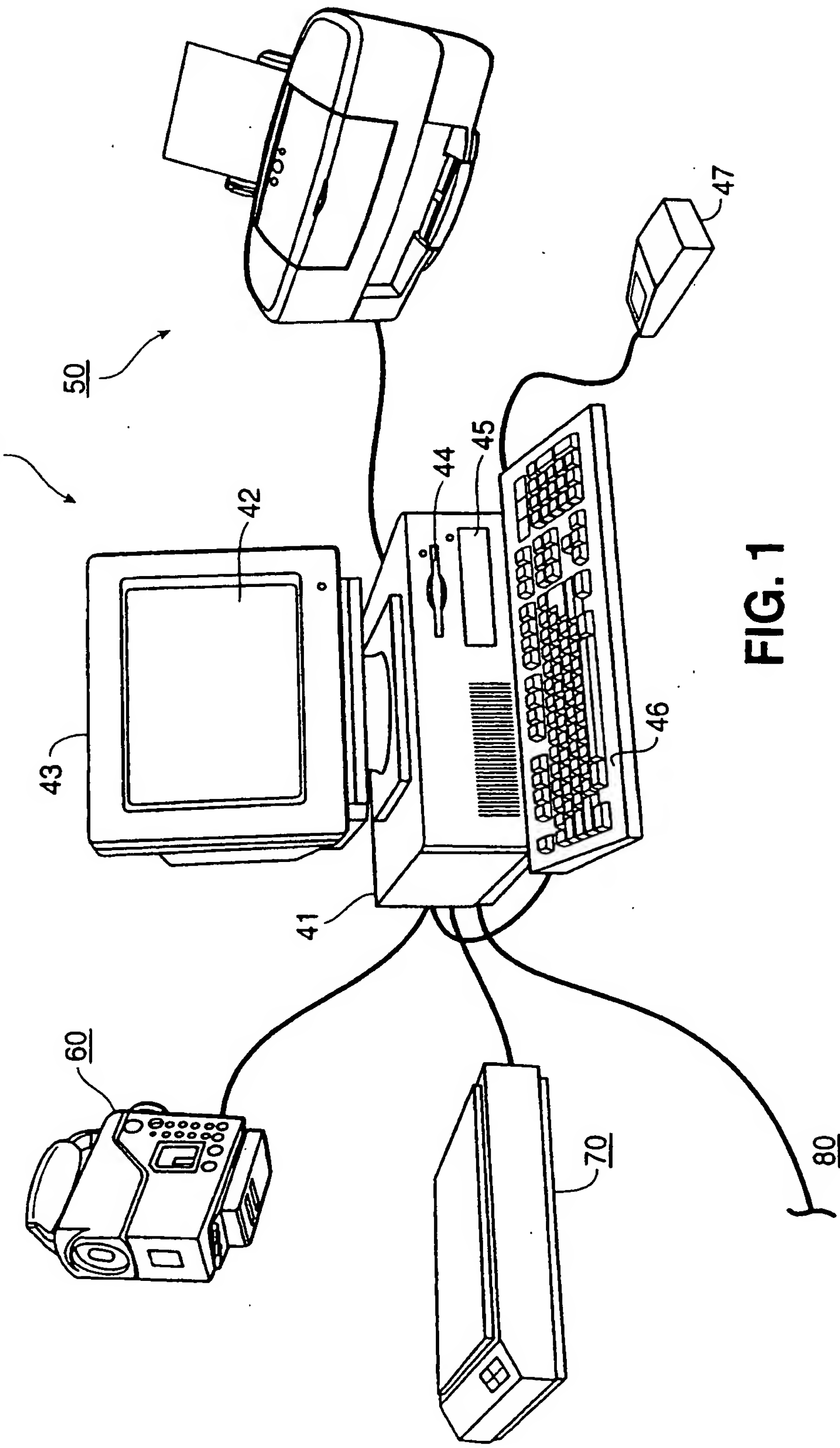
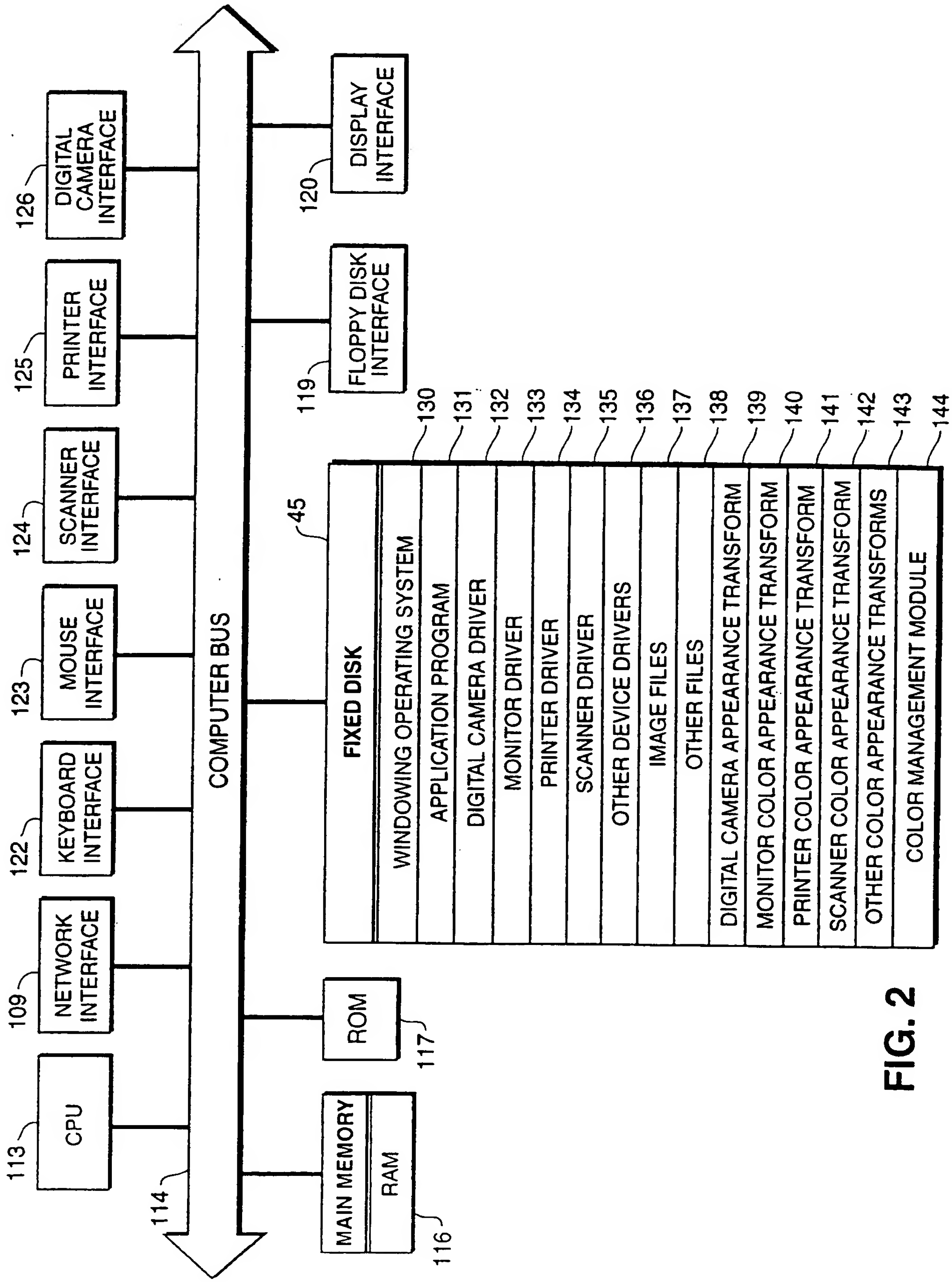


FIG. 1



113
CPU
109
NETWORK INTERFACE
122
KEYBOARD INTERFACE
123
MOUSE INTERFACE
124
SCANNER INTERFACE
125
PRINTER INTERFACE
126
DIGITAL CAMERA INTERFACE
114
COMPUTER BUS
MAIN MEMORY
RAM
116
ROM
117
45
FIXED DISK
WINDOWING OPERATING SYSTEM
APPLICATION PROGRAM
DIGITAL CAMERA DRIVER
MONITOR DRIVER
PRINTER DRIVER
SCANNER DRIVER
OTHER DEVICE DRIVERS
IMAGE FILES
OTHER FILES
DIGITAL CAMERA APPEARANCE TRANSFORM
MONITOR COLOR APPEARANCE TRANSFORM
PRINTER COLOR APPEARANCE TRANSFORM
SCANNER COLOR APPEARANCE TRANSFORM
OTHER COLOR APPEARANCE TRANSFORMS
COLOR MANAGEMENT MODULE
130
131
132
133
134
135
136
137
138
139
140
141
142
143
144
119
FLOPPY DISK INTERFACE
120
DISPLAY INTERFACE

FIG. 2

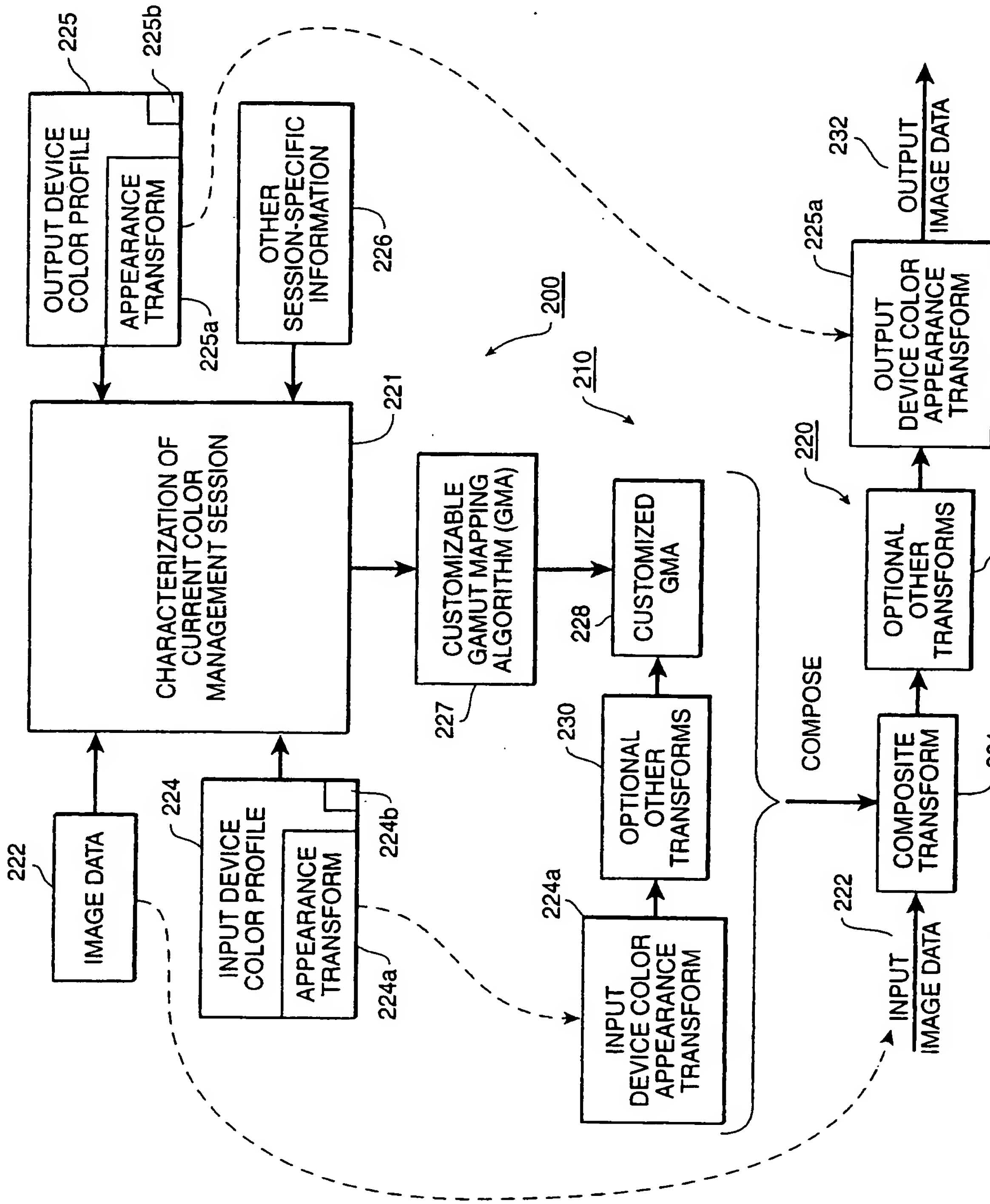

OUTPUT DEVICE COLOR PROFILE
APPEARANCE TRANSFORM
225
225b
225a
OTHER SESSION-SPECIFIC INFORMATION
226
CHARACTERIZATION OF CURRENT COLOR MANAGEMENT SESSION
221
200
210
CUSTOMIZABLE GAMUT MAPPING ALGORITHM (GMA)
227
CUSTOMIZED GMA
228
IMAGE DATA
222
INPUT DEVICE COLOR PROFILE
APPEARANCE TRANSFORM
224
224b
224a
OPTIONAL OTHER TRANSFORMS
230
INPUT DEVICE COLOR APPEARANCE TRANSFORM
224a
COMPOSE
COMPOSITE TRANSFORM
231
INPUT IMAGE DATA
222
OPTIONAL OTHER TRANSFORMS
234
220
OUTPUT DEVICE COLOR APPEARANCE TRANSFORM
225a
OUTPUT IMAGE DATA
232

FIG. 3

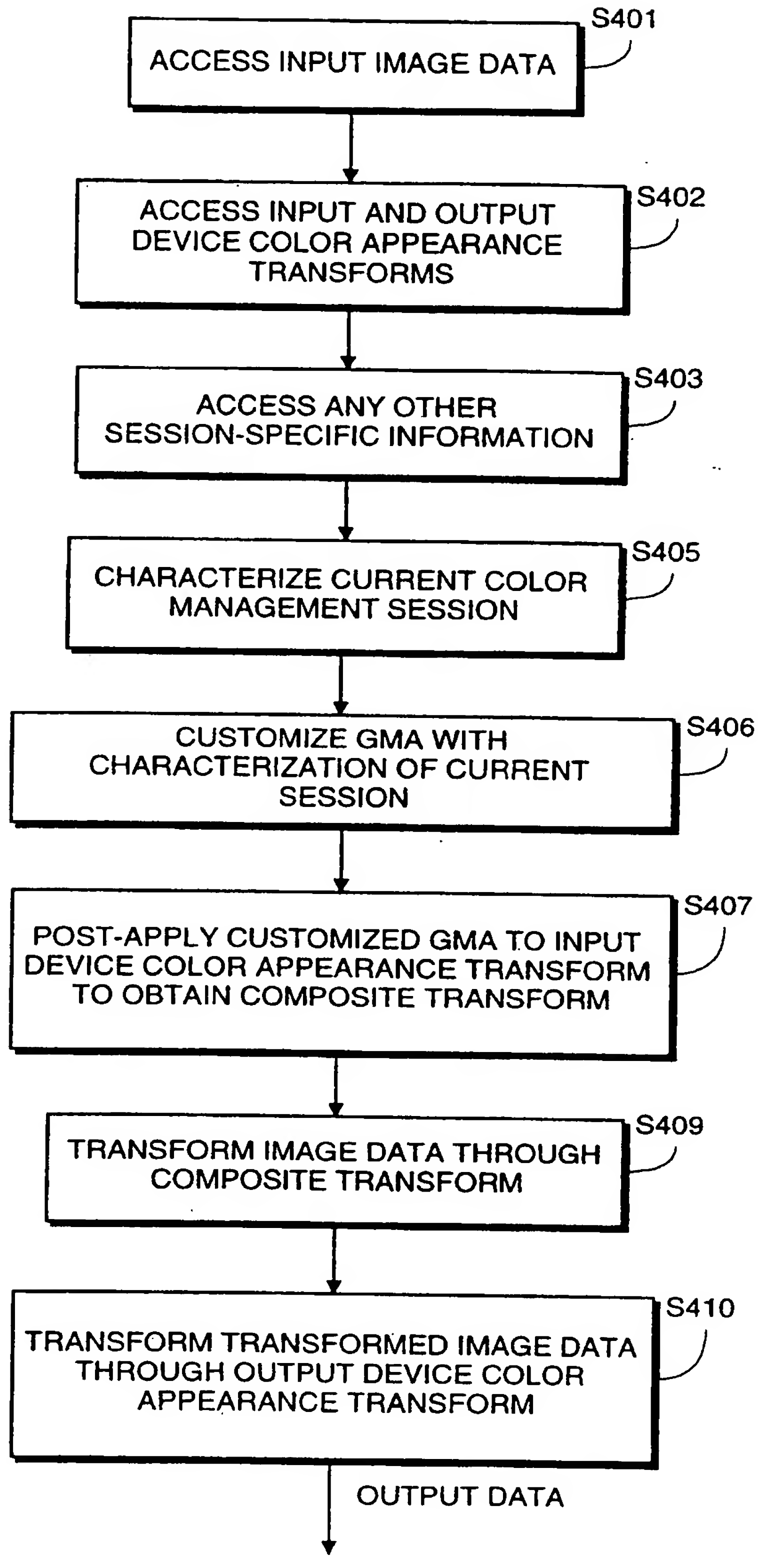
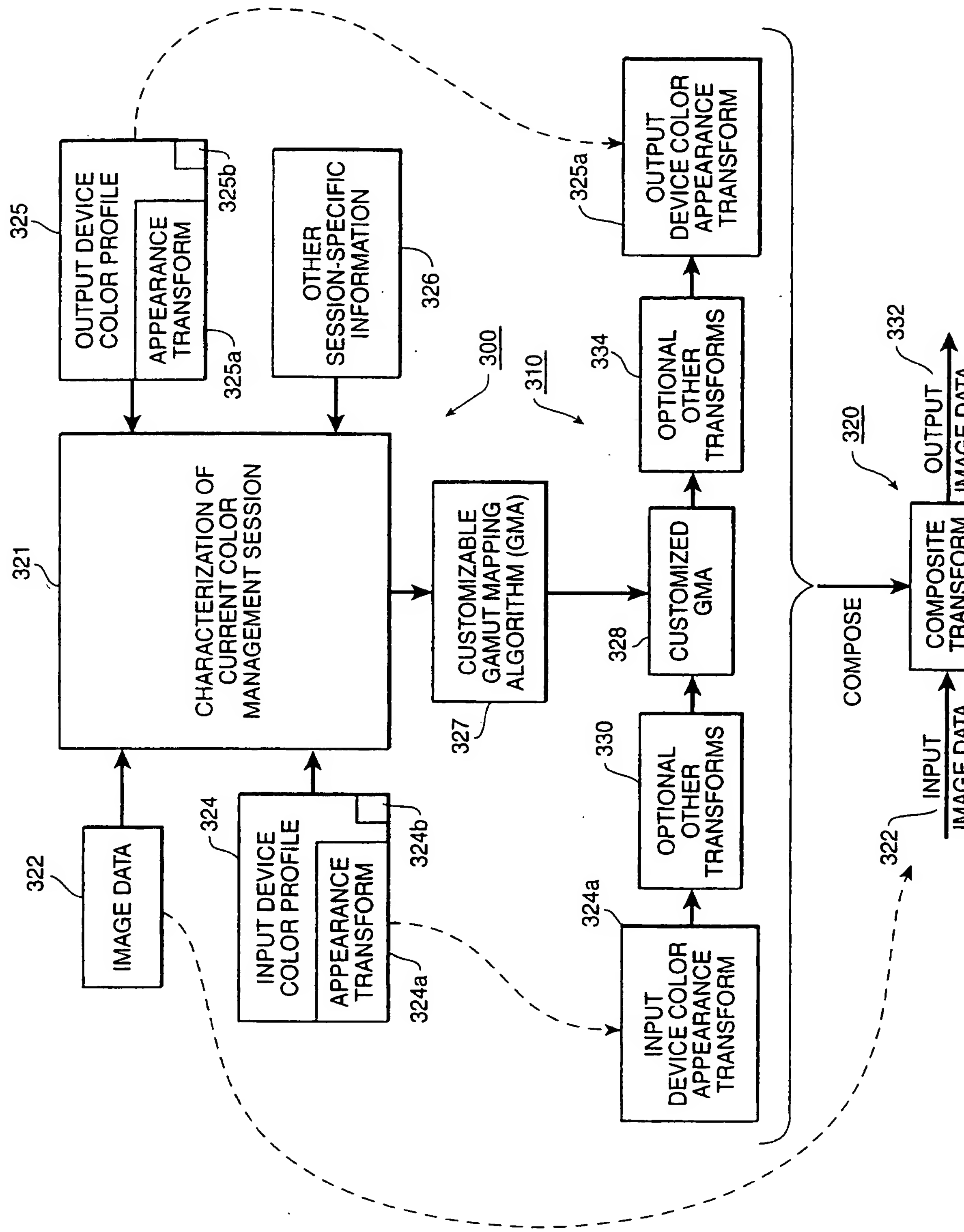

S401
ACCESS INPUT IMAGE DATA
S402
ACCESS INPUT AND OUTPUT DEVICE COLOR APPEARANCE TRANSFORMS
S403
ACCESS ANY OTHER SESSION-SPECIFIC INFORMATION
S405
CHARACTERIZE CURRENT COLOR MANAGEMENT SESSION
S406
CUSTOMIZE GMA WITH CHARACTERIZATION OF CURRENT SESSION
S407
POST-APPLY CUSTOMIZED GMA TO INPUT DEVICE COLOR APPEARANCE TRANSFORM TO OBTAIN COMPOSITE TRANSFORM
S409
TRANSFORM IMAGE DATA THROUGH COMPOSITE TRANSFORM
S410
TRANSFORM TRANSFORMED IMAGE DATA THROUGH OUTPUT DEVICE COLOR APPEARANCE TRANSFORM
OUTPUT DATA

FIG. 4



OUTPUT DEVICE COLOR PROFILE
APPEARANCE TRANSFORM
325
325a
325b
OTHER SESSION-SPECIFIC INFORMATION
326
CHARACTERIZATION OF CURRENT COLOR MANAGEMENT SESSION
321
IMAGE DATA
322
INPUT DEVICE COLOR PROFILE
APPEARANCE TRANSFORM
324
324a
324b
CUSTOMIZABLE GAMUT MAPPING ALGORITHM (GMA)
327
300
310
OUTPUT DEVICE COLOR APPEARANCE TRANSFORM
325a
OPTIONAL OTHER TRANSFORMS
334
CUSTOMIZED GMA
328
OPTIONAL OTHER TRANSFORMS
330
INPUT DEVICE COLOR APPEARANCE TRANSFORM
324a
COMPOSE
320
COMPOSITE TRANSFORM
331
OUTPUT IMAGE DATA
332
INPUT IMAGE DATA
322

FIG. 5

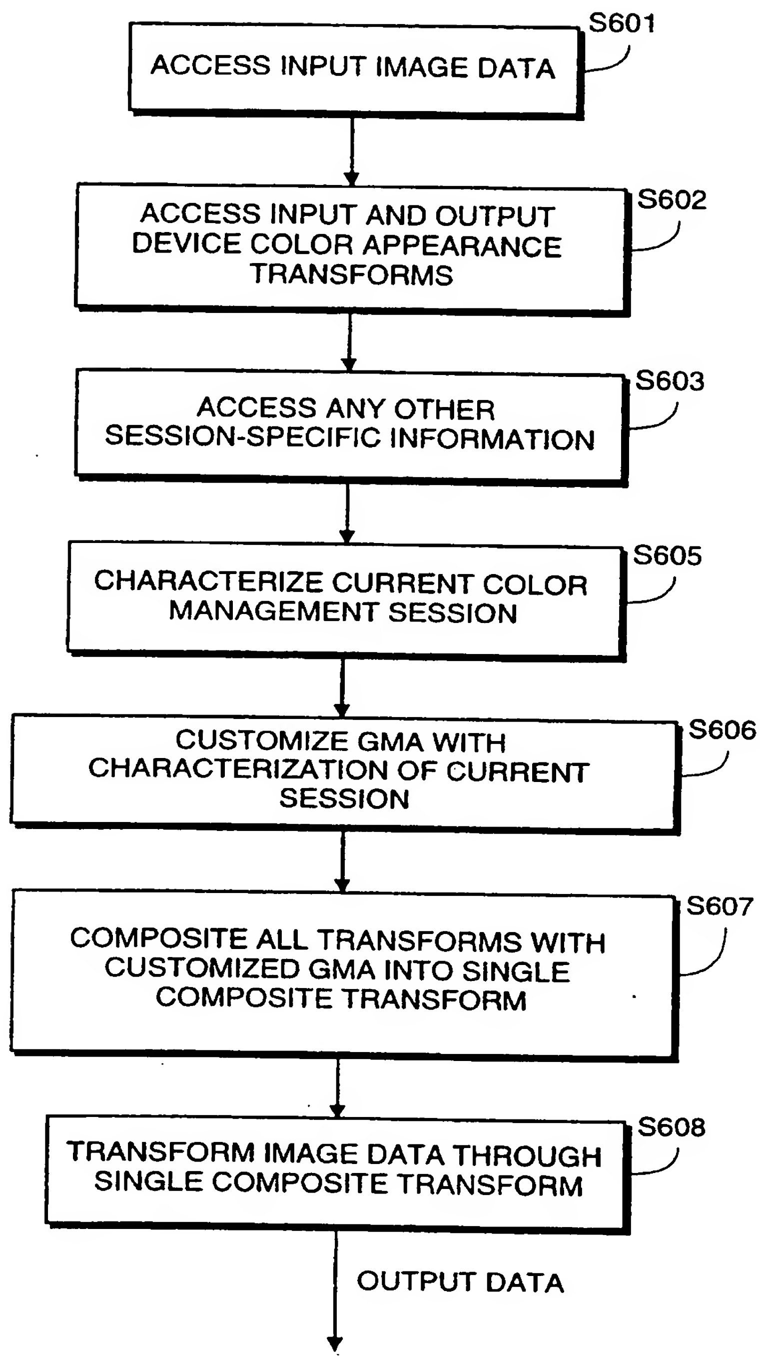

ACCESS INPUT IMAGE DATA
S601
ACCESS INPUT AND OUTPUT DEVICE COLOR APPEARANCE TRANSFORMS
S602
ACCESS ANY OTHER SESSION-SPECIFIC INFORMATION
S603
CHARACTERIZE CURRENT COLOR MANAGEMENT SESSION
S605
CUSTOMIZE GMA WITH CHARACTERIZATION OF CURRENT SESSION
S606
COMPOSITE ALL TRANSFORMS WITH CUSTOMIZED GMA INTO SINGLE COMPOSITE TRANSFORM
S607
TRANSFORM IMAGE DATA THROUGH SINGLE COMPOSITE TRANSFORM
S608
OUTPUT DATA

FIG. 6

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US00/31225

A. CLASSIFICATION OF SUBJECT MATTER

IPC(7) :G06K 9/36, 9/46
US CL : 382/164, 165, 166, 167, 167
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 382/164, 165, 166, 167, 167

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where apprppriate, of the relevant passages	Relevant to claim No.
X	US 5,208,911 A (NEWMAN et al) 04 May 1993, col. 6, lines 6-17.	1-22

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

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"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search
15 JANUARY 2001

Date of mailing of the international search report
02 FEB 2001

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